# APPENDIX C

## EMBEDMENT TECHNIQUES FOR CARLSON TYPE TRANSDUCER INSTRUMENTS

C-1. General. The following techniques are those that should be followed to insure an adequate installation of Carlson type transducers.

C-2. Strain Meter. A successful strain meter installation requires that each meter be aligned with reference to the structure axis or center-line as specified on the drawings, and that the concrete surrounding the meters be identical with that in the remainder of the structure. Obviously these goals cannot be achieved completely, but every effort should be made during placement operations to satisfy the conditions so far as practicable.

a. Single Strain Meters. Single strain meters are usually embedded near the top of a lift. In this case let the lift be topped off and the placing crew move away.

Step 1. Dig into the area for the full depth of the instrument and discard all aggregate over 3-in. size.

Step 2. Backfill sufficiently to provide a bed for the instrument.

Step 3. Make a hole for vertical or diagonal meters, using an electric laboratory vibrator or by driving a pointed 1-1/2-in. diameter steel pipe into the backfilled concrete, and insert meter in the hole. Horizontal meters are merely laid flat on the prepared bed.

Step 4. Check angles, direction and depth, using the machinist's protractor and level, held against the end flange.

Step 5. Carefully vibrate or hand-puddle around the meters. If job vibrators are used, care should be taken to avoid violent or excessive vibration which might disturb the meter alignment or overvibrate the backfilled concrete.

Step 6. Complete backfilling by hand with 3-in. maximum aggregate concrete, and hand-puddling up to grade.

b. Interior Groups of Meters. More elaborate preparations and facilities are required on interior groups of meters to assure proper installations in the limited time available before the concrete attains its initial set. It is desirable that prior to the time concrete is placed in the intended meter location the meters be brought into the block and grouped according to their arrangement in the monolith, and that tools, equipment, templates, and spare meters be placed in a conveniently accessible location. One procedure for placement of a meter group is as follows:

Step 1. Place the temporary block-out frame on top of the lift concrete when it has reached an elevation about 12 in. below final grade.

Step 2. Finish off remainder of lift outside the frame.

Step 3. Explore the bed with shovels and remove cobbles over 3 in. in size to a depth of 4 in.

Step 4. Set template, using survey points previously marked, and place meters in approximate location, running cables out beneath block-out frame and template.

Step 5. Using an electric laboratory vibrator or a pointed 1-1/2-in. diameter steel pipe, punch holes at the proper location in the prepared bed to receive the vertical and inclined meters. The holes should be made sufficiently deep so as to contain all but about 2 in. of the instrument, and the instrument checked for vertical or slope by placing the protractor level across the flanged end of the meter. The space between the meter case and the sides of the hole is carefully filled with stiff concrete containing little or no coarse aggergate, and thoroughly compacted. Inclination of the meter should be checked with the protractor during this operation. Horizontal meters are placed in their proper location on top of the prepared bed and aligned and levelled. This is the stage of the installation shown in Figure C-l.

Step 6. Cover each instrument immediately with hand-placed 3-in. maximum aggregate concrete until a 3-in. thick cushion is built over and around each meter.

Step 7. After the concrete has been allowed to stiffen slightly, remove the template and block-out frame, and fill the remainder of the hole with regular fresh concrete. The concrete should not be dumped or thrown into the hole, but should be placed carefully with shovels to avoid disturbing the embedded meters or damaging them.

Step 8. After the hole is filled, it may be lightly vibrated or hand-puddled to consolidate the covering concrete, extreme care being taken to avoid walking over the area or otherwise disturbing the instruments. A board cover or barrier will serve to protect the area during the lift exposure period.

c. Alternate Procedure for Interior Groups. A second procedure for embedding strain meters, particularly useful for groups of 10 or more instruments, involves the use of a special spider mounting frame, Figures C-2 and C-3, which simplifies alignment of the meters. Details are as follows:

Step 1. Level off a concrete bed 2 ft below the ultimate elevation of the lift.

Step 2. Mark the meter group location with a light board framework and finish up the lift around this location.

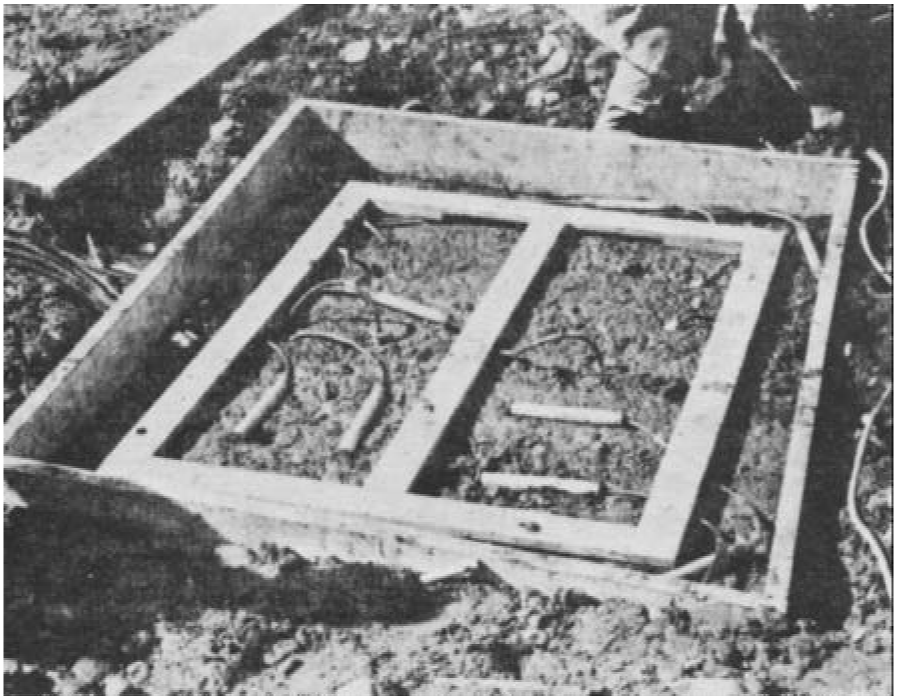

Figure C-1. Strain Meter Group Ready to be Covered (Courtesy of the Bureau of Reclamation).

Step 3. Make final assembly of strain meters on the spiders on a plywood or wood working platform nearby the location, and lay out and bunch cables ready for embedment.

Step 4. Explore the levelled-off bed with shovels and remove cobbles over 3 in. in size near the bedding surface. Consolidate lightly with vibrator.

Step 5. Place spider and attached meters in position, and check orientation and level.

Step 6. Carefully place concrete by hand around meters, and hand-puddle or carefully vibrate within the spider with a small laboratory vibrator. As covering of the meters begins, the shoulders of the surrounding finished lift should be lightly vibrated to avoid the possibility of sudden sloughing of the sides onto the spider assembly.

Step 7. Erect a protecting wood barrier to protect the area during the lift exposure period.

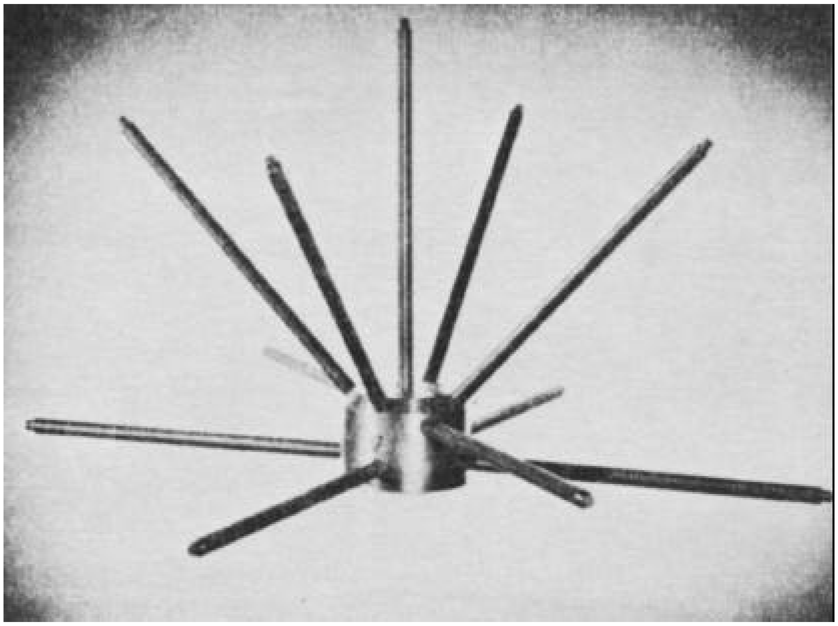

Figure C-2. Carlson Strain Meter Spider. From "Measurement of Structural Action in Dams" by J. M. Raphael and R. W. Carlson.

Figure C-3. Strain Meters Mounted on Spider (courtesy of the Bureau of Reclamation).

d. Surface Strain Meters. Boundary groups, or surface strain meters, consist of several meters (from three to six) placed at distances varying from 3 in. to 3 ft from a surface of the structure with each meter arranged parallel to the concrete face and in a vertical plane. The positioning of the meters at the required distance from the face, in a vertical plane and at the proper slope can be satisfactorily attained by utilizing special pipe brackets bolted or fastened to the top of the forms. A set of such brackets in place ready for concreting is shown in Figure C-4. Each bracket holds a length of 1-1/2-in. pipe, swedged shut at the bottom end, at the proper distance from and parallel to the form surface. When the concrete is placed, as in Figure C-5, each pipe forms a hole slightly larger than the meter diameter. A shallow hole about B-in. deep is dug around each pipe; and after the concrete has stiffened slightly the bracket screws are removed, the pipes pulled out and the meters placed in the holes. The space between the meter case and the sides and bottom of the hole is filled with mortar and carefully tamped to insure complete contact with the instrument. Figure C-6 shows the installation at this stage, The depressions around each meter are brought up to grade by carefully placing concrete with shovels and hand-tamping. A board cover or barrier will protect the area while the concrete is hardening.

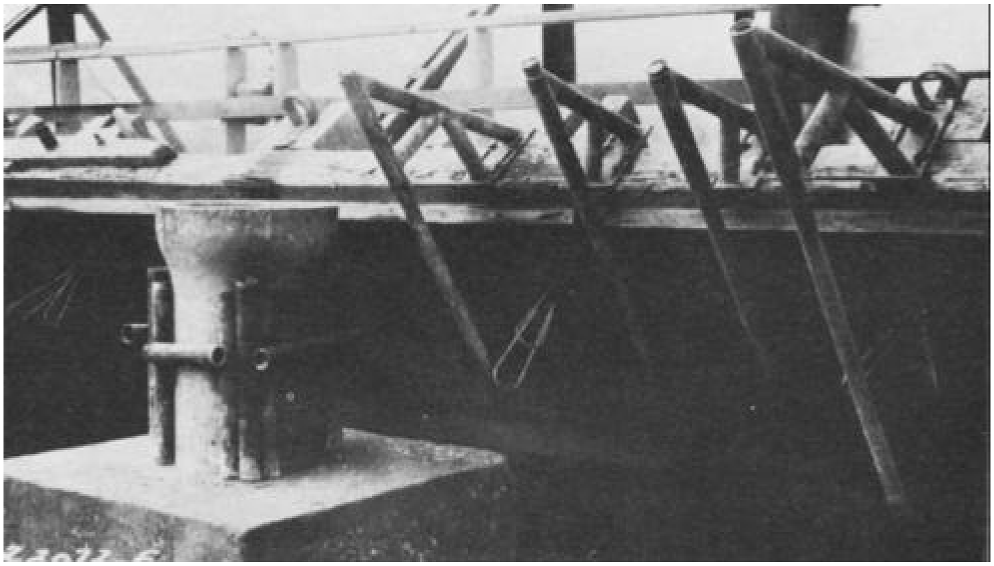

Figure C-4. Pipe Brackets for Locating Boundary Strain Meters - Prior to Placing Concrete (courtesy of the Tennessee Valley Authority).

Figure C-5. Pipe Brackets for Locating Boundary Strain Meters - After Concrete is Placed (courtesy of the Tennessee Valley Authority).

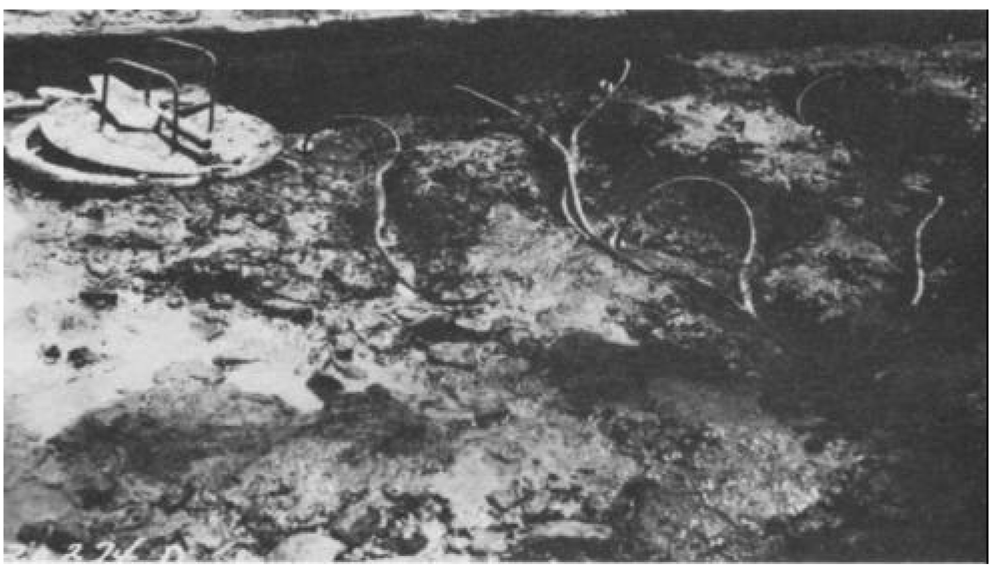

Figure C-6. Boundary Strain Meters in Place (courtesy of the Tennessee Valley Authority).

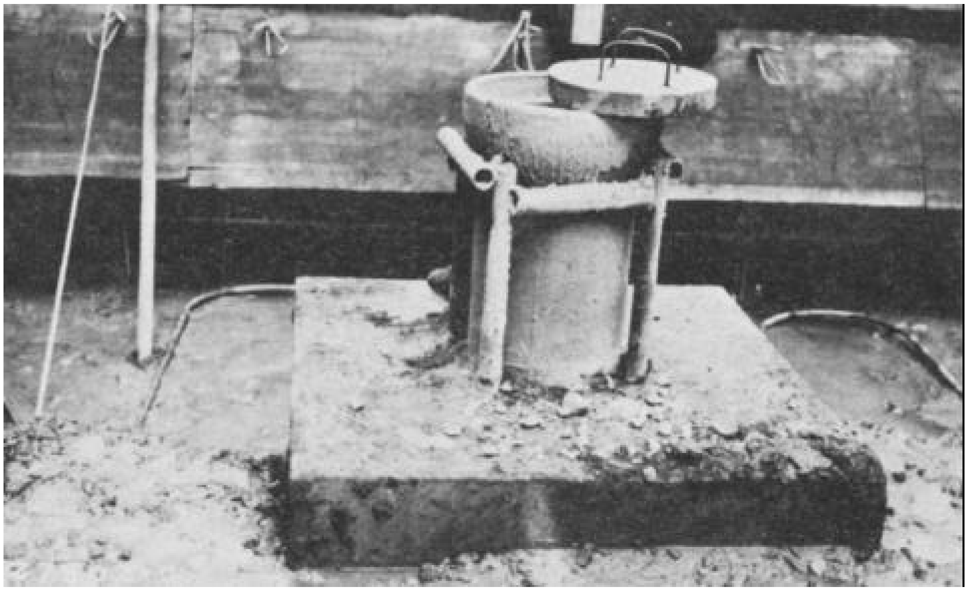

Figure C-7. No-Stress Test Specimen Pipe Containter (courtesy of the Tennessee Valley Authority).

C-3. "No-Stress" Strain Meters.

a. Purpose. For the purpose of measuring independently the volumetric effects of temperature and moisture changes and chemical action within a large structure, "no-stress" strain meters are frequently provided in conjunction with strain meter groups. This can be accomplished by embedding an ordinary strain meter in typical mass concrete which is isolated from deformations due to loading, but is responsive to the temperature, moisture, and growth changes prevailing in the mass concrete of the structure.

b. Typical Installation. One arrangement, used successfully on previous installations, is to provide a cavity in the lift near the strain meter group by embedding a 3- or 4-ft length of 15-in. diameter concrete pipe so that the flange extends about 3 in. above the lift surface. A concrete pedestal is constructed around the bottom of the pipe to support it and hold it in place during placement of the concrete lift, and a precast concrete cover is provided. The pipe and upper portion of the pedestal are shown in Figure C-7. The strain meter is suspended in the center of a 12- by 24-in. cylinder specimen mold (of a type which will permit easy stripping), and the mold filled with fresh concrete taken from a typical lift batch adjacent to the strain meter group. The 12-in. diameter mold permits the use of up to 3-in. aggregate concrete, so that the no-stress cylinders will closely represent the concrete in the lift. At locations where 6-in. aggregate concrete is being used, cobbles larger than 3 in. are removed from the concrete placed in the cylinder mold. Figures C-8 and C-9 show details of the no-stress cylinder cavity. The day after the cylinders are cast, the molds are removed, the cavity cleaned and water removed, the cylinder placed in the cavity, and the precast cover placed and sealed.

c. Alternate Installations. A second scheme, used by the Bureau of Reclamation, is to embed two strain meters, one vertically and one horizontally, near the top of a concrete lift, and then place a 3-ft diameter 3/8-in. thick steel plate over the lift surface. The plate is held 2 or 3 in. above the concrete surface by a circumferential rim or lip, which isolates the meters from the effects of vertical load. The length change indicated by the vertical meter includes the deformation resulting from the horizontal strains modified by Poisson's ratio, while the horizontal strain meter aids in the evaluation of the Poisson ratio effect. A third scheme, developed by Serafim, involves the use of a double-walled, double-bottom copper container which serves to protect the concrete containing the meter from strains due to load, yet provides continuity of the concrete so that other volumetric changes may take place without restraint.

Figure C-8. No-Stress Meter Cylinder with Mold Partially Removed (courtesy of the Tennessee Valley Authority).

C-4. Joint Meter.

a. Arrangement. Whenever possible the joint meter installation should be so arranged that the meter unit and the cable lead are placed in a following block. While other arrangements are possible, they require more care in placement and frequently involve field splicing of the cable and/or special protection facilities for cable and meter. The most convenient location for the meters is from 6- to 10-in. below the top of a lift.

Figure C-9. No-Stress Meter Cavity and Cover (Courtesy of the Tennessee Valley Authority).

b. Meter and Cable in Following Block. The socket plug is nailed, with its slotted side against the form, to the interior surface of the form at the desired location, as shown in Figure C-10. The meter socket is then screwed onto the plug, completing the preliminary step in the meter installation, Figure C-11. A joint meter socket being covered by concrete in a leading monolith is shown in Figure C-12. Should it be found that the bond between the socket and surrounding concrete is not adequate to prevent displacement during form removal operations, short metal anchors may be welded onto the socket prior to placement. After concrete in the following block has been brought up to elevation of the joint meter location, remove about 1 sq ft of the fresh concrete to a depth necessary to expose the plug in the end of the socket embedded in the leading block. Remove the plugs as shown in Figure C-13 and insert the joint meter unit, screwing it in tightly, as in Figure C-14. The meter should then be manually forced into position which will provide sufficient available operational range in the meter to cover the magnitude and direction of the expected joint movement. Normally a completely closed position or a midrange position will be satisfactory. The initial meter position is determined by making ratio readings with the portable test set. Backfill with concrete around the meter, tamping carefully to obtain a good embedment without displacing the meter. Several boards laid on the completed lift surface at the meter location will serve to protect the installation until the concrete has hardened.

Figure C-10. Joint Meter Socket Plug (Courtesy of the Tennessee Valley Authority).

Figure C-11. Joint Meter Socket Screwed onto Plug (Courtesy of the Tennessee Valley Authority).

Figure C-12. Joint Meter Socket in Place (Courtesy of the Tennessee Valley Authority).

c. Meter in Following Block, Cable in Leading Block. When it is necessary or desirable that the cable lead be located in the leading block, the most satisfactory arrangement is to embed the required length of cable (prior to attachment to the joint meter) in the lift immediately above that containing the meter socket, terminating the cable end to be attached to the instrument in a 1-ft square block-out near the socket location. At least 5 ft of free cable should be coiled into this recess. After the meter unit is installed, as described in the preceding paragraph, the short cable lead attached to the instrument is run vertically to above the lift surface, and concrete is carefully placed around the meter unit. The following day, after the concrete has hardened, the short instrument lead projecting above the lift surface is joined to the free end of the previously embedded cable with a wrapped field splice. Since the embedded cable crosses a contraction joint, provision must be made at the crossing point to permit the embedded cable to accommodate the expected differential monolith movements. This is done by coiling one or two loops of slack cable in the block-out, and providing a cover for the recess when concrete is placed in the adjacent lift. Figure C-15 shows the meter and cable arrangement for this scheme.

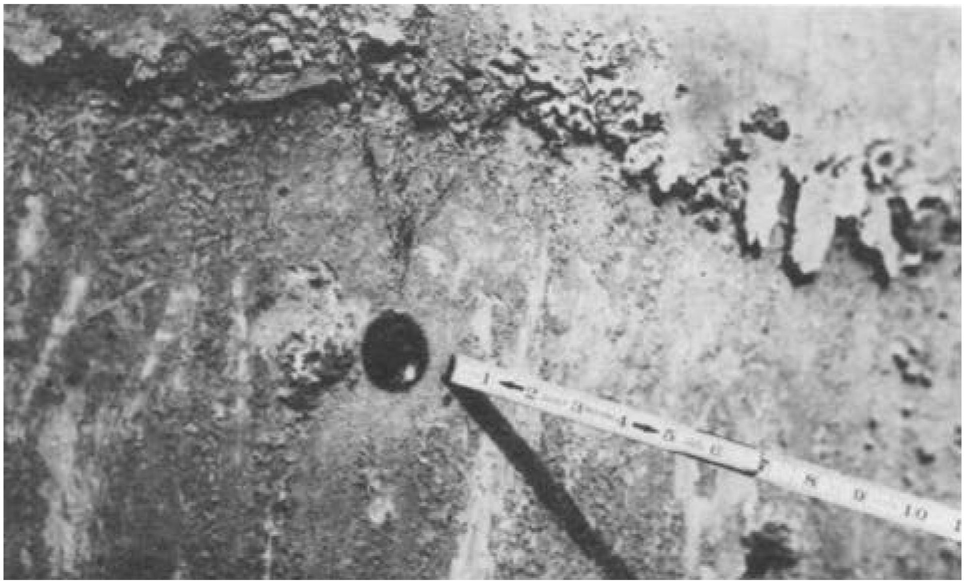

Figure C-13. Embedded Joint Meter Socket with Plug Removed (Courtesy of the Tennessee Valley Authority).

Figure C-14. Joint Meter Unit Screwed into Socket (Courtesy of the Tennessee Valley Authority).

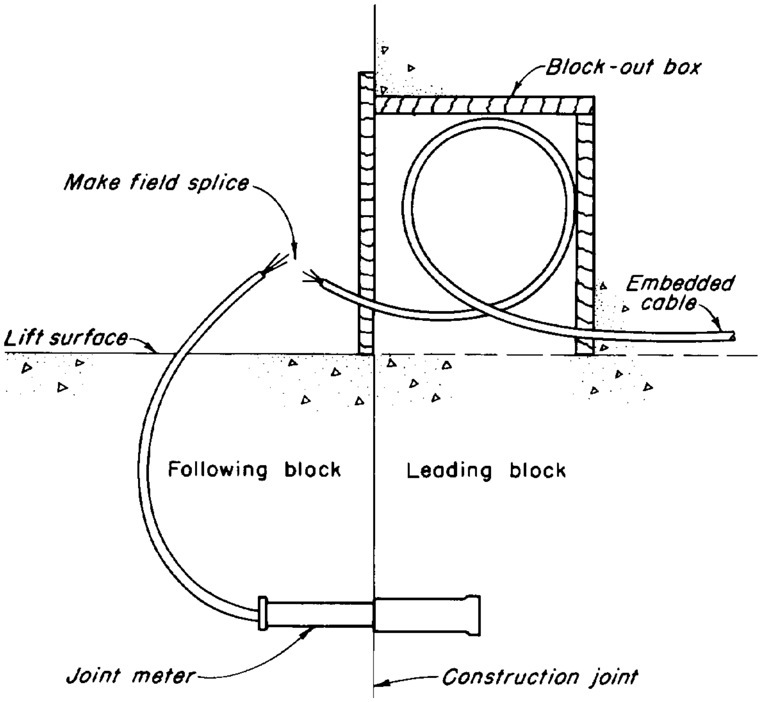


Figure C-15. Joint Meter in Following Block, Cable in Leading Block. (Prepared by WES)

d. Meter and Cable in Leading Block. The necessity for field-splicing the instrument cable in the following block to the embedded cable in the leading block can be avoided by turning the joint-meter end-for-end and embedding the meter unit and cable lead in the leading block and the socket in the following monolith. To accomplish this, a hole slightly larger in diameter than the meter case at the bellows section is drilled through the lift form of the leading monolith at the desired location, and the meter unit inserted for one-half its length with the cable end inside the forms. The socket is screwed onto the end of the meter projecting from the exterior face of the form, and fastened to the exterior of the form so as to hold the meter securely during concrete placement. The socket is removed to permit form removal, which must be done carefully to avoid displacing the partially embedded meter. The socket is then replaced, and suitable provisions made to protect the projecting socket during subsequent operations. While this procedure eliminates the field splice, considerable opportunity exists for damage to the sensitive meter unit during form removal operations and during the period while concrete is being placed in the following block.

C-5. Stress Meter.

a. Embedment Procedure. Proper and satisfactory operation of the stress meter is dependent almost entirely upon obtaining a perfect contact between the meter plate and the adjacent concrete. An embedment procedure, to be acceptable, must avoid the formation of air pockets and eliminate so far as practical the collection of water beneath the meter which always occurs during bleeding.

b. Meter on Horizontal Plane. Placement of the stress meter in horizontal (stem vertical) and diagonal (stem sloping) positions may be accomplished by providing a hole or depression in the top of the lift, as shown in Figure C-16 and bedding the meter the following day after the lift concrete has hardened. The complete step-by-step procedure recommended is as follows:

Step 1. Prior to starting concrete placement in the lift, the meter and about 4 ft of attached cable is placed in a wooden box only slightly larger than the plate and about 12- to 15-in. deep. When concrete has reached an elevation about 12 in. below the top of the lift, the box containing the meter is placed at the desired location, and lift placement completed. The meter cable leads are placed and buried during this period in the usual manner, except for the 4 ft of surplus cable which remains in the box. This cable slack is necessary in order to allow some freedom in placing the meter during embedment operations.

Step 2. When the lift has been completed, the box containing the meter is removed from the concrete and a conical cavity left in the lift surface. The side slopes and bottom should be sloped or levelled as required, and left in a reasonably smooth plane condition. Avoid excessive trowelling or floating. A diagrammetric sketch of a prepared cavity, with 45° slopes suitable for diagonal meters, is shown in Figure C-16. The boxed meter is replaced in the cavity, and a heavy wooden box or cover is placed over the hole to protect against damage.

Step 3. The following day, after the concrete has hardened, the hole is cleaned to remove all laitance and loose material so as to provide a good bond with the new concrete. The areas upon which the meters are to be placed should be chipped to remove projecting corners of aggregate, and wire brushed to expose a good bonding surface. All water should be removed from the hole, and provisions made to prevent curing water from entering the cavity during the meter placement operation.

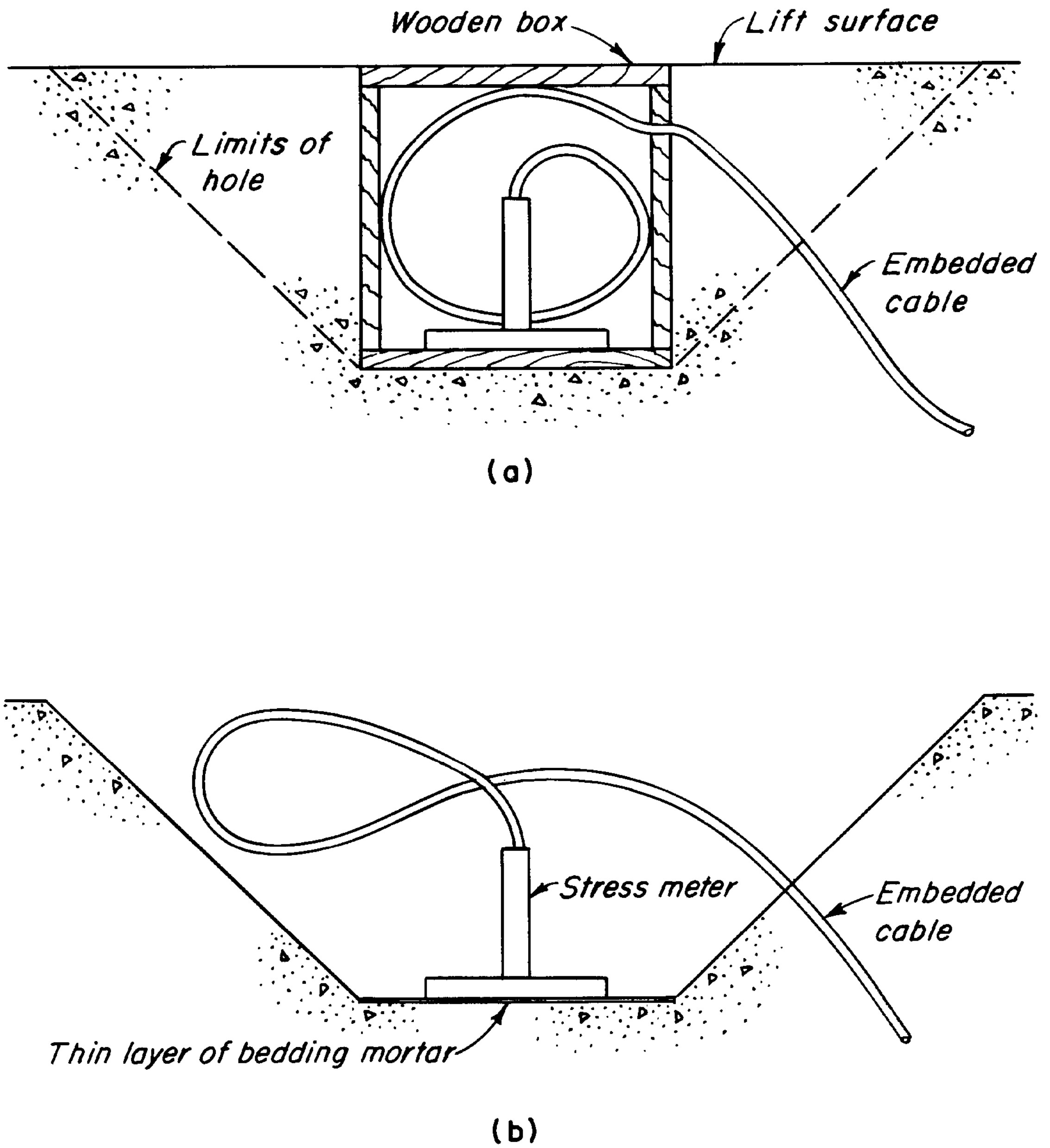


Figure C-16. Cavity in Lift Surface for Installation of Stress Meter. (Prepared by WES)

Step 4. About 1 hr before placing the stress meter, a sanded grout is prepared, consisting of 80 g of cement and 120 g of sand passing the No. 30 sieve with only enough water to produce a plastic consistency. It is recommended that one or more trial mixes be made to establish the amount of water required for the mortar. Just before placing the meter, a thin film of grout, made by adding water to a small amount of the prepared mortar, is brushed over the smoothed concrete surface in order to dampen and lubricate it. The remaining mortar is reworked without additional water, placed on the dampened surface where the meter is to be located, and shaped into a rough cone. Then, with a reciprocal rotary motion, the meter is pressed down on this mortar cone causing it to squeeze outward and appear around the rim of the meter. The mortar bed, after the meter has been pressed into its final position, should be not more than 1/8 in. in thickness (preferably 1/16 in.). Weights totaling 15 to 20 lb should be uniformly distributed over the upper surface of the meter plate, as shown in Figure C-17, to hold the meter in close contact with the mortar. A small tripod table carrying the proper weight load has been found convenient and assures a uniform applied pressure.

Figure C-17. Stress Meter in Place (Courtesy of the Tennessee Valley Authority).

Step 5. After the mortar has set slightly (from 2 to 3 hr), fresh concrete similar to that in the remainder of the lift should be carefully placed in thin layers and thoroughly hand-compacted. The tripod and weights may be removed after the first or second layer has been placed. Care should be taken in placing the cop-crete to avoid displacing the meter. After the hole is completely back-filled, it should be covered with a layer of boards for protection until the concrete has hardened. Normal curing operations should be resumed as soon as the fresh concrete has hardened sufficiently.

c. Meter on Vertical Plane. Placement of stress meters in a vertical position (stem horizontal). is done in fresh concrete of the lift and presents no difficult problem. After concrete placement in the lift has been completed, a hole about 12 in. in depth is dug at the meter location. The meter is laid in place and concrete, with the large cobbles removed, placed in thin layers around the instruments and thoroughly tamped into place, as in Figure C-18. Alignment and position of the meter should be checked and maintained during placement of the concrete backfill. A temporary board cover over the meter location will protect the installation until the concrete has hardened.

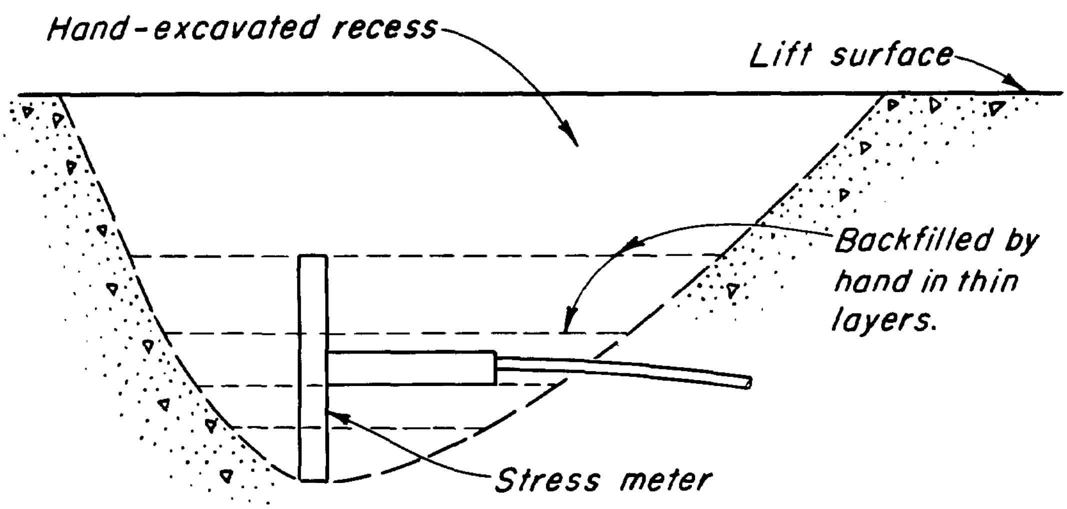


Figure C-18. Position of Stress Meter for Measuring Stress on Vertical Plane. (Prepared by WES)

C-6. Pore Pressure Cell. The pore pressure cells are usually located near the top of a lift, where placement can be accomplished after concreting in the area has been completed. A hole just large enough to accommodate the instrument and about 12 in. deep is dug at the desired location. The meter is laid horizontally in the hole, normal to the exterior surface of the concrete, and with the porous plug at the desired distance from the water-concrete contact plane. Frames or brackets to hold the meters in position during embedment should not be used, since they would possibly provide a leakage path directly to the cell. Concrete is placed by hand around the instrument and tamped sufficiently so as to obtain a good contact between the body of the meter and the surrounding concrete. Avoid excessive tamping or working of the concrete which would result in a highly impermeable zone around the meter and adversely affect the normal buildup of hydrostatic pressures being measured. Where several cells are located in a lift at different distances from the water-concrete contact surface, the meters should be arranged in echelon formation, at least 3 ft apart, in order that the instruments near the surface will not interfere with the development of hydrostatic pressures at the instruments farther from the face. After embedment, a temporary cover of boards laid over the meter locations will afford protection until the concrete has hardened.

C-7. Resistance Thermometer.

a. Instrument Location. Embedment of the resistance thermometer is a simple procedure since orientation is usually not important and careful placement of concrete around the meter is not a requirement. When the location of the instrument relative to the top or bottom of a lift is not important, the thermometer is simply laid in a shallow (6 or 8 in.) hole, covered immediately by shovelling or pushing fresh concrete over it and the area lightly vibrated. Installation of several thermometers or thermometer groups on a single horizontal plane within a lift is most easily done by placing them at the bottom of the lift. The meters should be taped or tied securely by means of wires or wire loops embedded in the top of the previous lift at approximately the proper locations.

b. Spacing. For accurate spacing of thermometers at various heights in a lift, the meters may be taped to a pole or rod which is embedded in the previous lift or otherwise maintained in a vertical position. Wood poles or 1/2-in. diameter bakelite tubes are recommended because of their favorable thermal properties. Other materials of low heat conductivity may be satisfactory, if in the form of thin-walled tubes. Reinforcing bars should not be used for this purpose.

c. Locations near Exposed Surfaces. Thermometers located within approximately 3 ft of exposed concrete surfaces or bulkhead faces subject to daily temperature variations must be placed accurately at their intended distance from the surface or face. Instruments must be secured firmly in position in some manner, since the placement of adjacent fresh concrete and manipulation of the vibrator equipment frequently will cause a relatively large displacement of a "free-floating" thermometer. The preferred method is to embed tie wires in the surface of the previous lift, place the thermometers on the hardened concrete lift surface and fasten them securely in their proper location by means of the tie wires. A second method, used when it is desired to place the thermometers within a concrete lift, consists of a light-weight bracket of low heat conductivity material fastened to the interior form surface holding the thermometer at the desired distance from the form. Care is required in removing the forms and detaching the brackets therefrom to avoid dislodging the embedded meter. The brackets should be as small as feasible so as not to interfere with the normal movement of heat between the surface and the thermometer location, and of a material whose specific heat and thermal conductivity are of the same general magnitude as those of concrete. Thermometers in groups should be arranged in echelon formation in order that each meter will not interfere with the movement of heat between the surface and other instruments in the group.

*U.S. GOVERNMENT PRINTING OFFICE: 1987-718-285/1193